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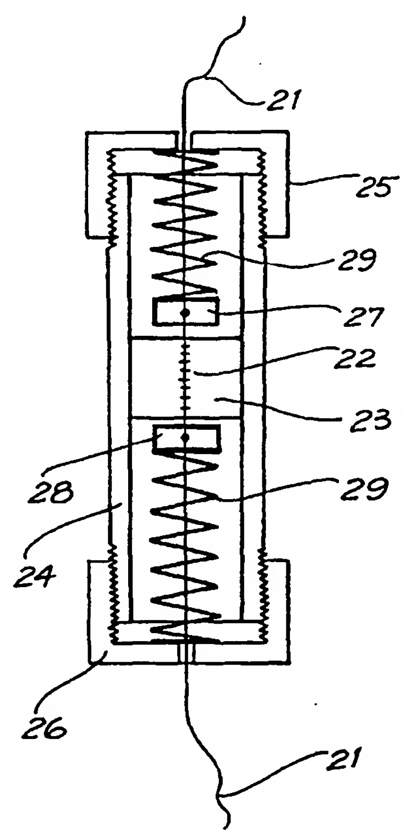
(54) Title: VARIABLE PROPERTY LIGHT TRANSMITTING DEVICE

(57) Abstract

A method of varying the characteristics of a light transmitting device such as an in-fibre Bragg grating. As applied to a Bragg grating (22), the method comprises the steps of loading the fibre (21) and, by use of cladding (23), constraining a portion of the fibre (21) that contains the grating (22) in a manner such that the grating-containing portion of the fibre is differentially elongated in the direction of light propagation. A strain gradient is thereby induced in the grating containing portion of the fibre. Various light transmitting devices, which incorporate an optical fibre which exhibits a strain gradient over a portion of its length in the direction of light propagation, are also disclosed.



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VARIABLE PROPERTY LIGHT TRANSMITTING DEVICE

TECHNICAL FIELD

This invention relates to a method of varying the properties of a light transmitting device and to a device *per se* when produced by or arranged to implement the method of the invention.

The invention may be employed in the context of varying the characteristics of an in-fibre Bragg grating and, thus, be employed in the fabrication of chirped gratings for use in dispersion compensation in long-haul, high bit-rate transmission systems. However, whilst the invention is introduced and described generally in the context of Bragg gratings it will be understood that it does have broader application, to the control or variation of light transmission and to the detection and/or measurement of conditions that influence the light transmitting properties of devices.

BACKGROUND ART

Various techniques have been developed for writing gratings into optical fibre, including the now extensively used transverse holographic method first described by Meltz et al in 1989. Also, a number of proposals have been made for the fabrication of chirped gratings, involving variation of the side-writing fringe spacing or variation of the refractive index in the direction of the fibre axis, for example by tapering the fibre. Tuning of the operating wavelength of an in-fibre grating is also effected using various techniques, including subjecting the fibre to high temperature, strain and pressure.

Post fabrication tuning enables a degree of control to be exercised over the desired centre frequency of the grating but the physical changes created in the fibre by applied forces are normally uniformly distributed along the length of the fibre. Thus, whilst a uniform shift may be achieved, the known tuning techniques do not permit the creation of a grating in which the resonant frequency or Bragg frequency is a function of position

along the length of the grating.

The Bragg frequency at an axial position within a grating is dependent upon the optical path length within each grating period and, thus, depends on both the period and the average refractive index. Therefore, chirped gratings may be achieved by varying either the grating period or the average refractive index or both. Axial strain may be imposed to increase the local spatial Bragg period and, thereby, increase the optical path length in the period. However, as abovementioned, strain applied to a grating by prior art techniques results in the imposition of strain which is substantially uniform along the length of the grating, this producing a uniform Bragg frequency shift and no change in the shape of the reflection spectrum of the grating.

DISCLOSURE OF THE INVENTION

The present invention in one of its applications is directed to a method which permits post-fabrication tuning of an in-fibre grating in a manner which provides for differential variation of the spatial period and, thus, variation of the Bragg frequency with position along the length of the grating.

Broadly defined, the present invention provides a method of varying the transmitting properties of a light transmitting device that exhibits strain-related transmitting characteristics. The method comprises loading and, by use of a cladding, constraining the device in a manner such that the device is differentially elongated over at least a portion of the length of the device in the direction of light propagation whereby a strain gradient is induced in the device in the direction of light propagation.

The invention may be defined in an alternative way as providing a light transmitting device *per se*. The device has a light transmitting portion which exhibits a strain gradient in the direction of light propagation. The strain gradient is created by loading the device and, using a cladding portion of the device, constraining the

light transmitting portion in a manner to effect differential elongation of at least a portion of the length of the light transmitting portion in the direction of light propagation.

The invention as above defined may be realised in various practical embodiments and be applied to various light transmitting devices, including optical fibres and planar waveguides. For example, when the invention is applied to a device which incorporates an optical fibre, a portion of the length of the fibre (including its own cladding) may be clad with an object or substance which permits constrained movement between the fibre and the cladding and, hence, causes differential elongation of the fibre in the direction of light propagation. When in this form and when a force is applied to one end of the fibre (or different forces are applied to the fibre at opposite ends of the clad portion), a graded constraining force (i.e. a force which varies in magnitude with position along the length of the fibre) will be exerted on the fibre along the length of the clad portion. Thus, a strain gradient will be induced in the clad portion of the fibre.

The cladding which is employed to constrain the fibre may be that which clads the core of the fibre or it may be additional to that which conventionally clads the core. In the latter case, the cladding which is used to constrain the fibre may be composed of a substance which is used to secure the optical fibre to a substrate or other support.

In an alternative form of the invention, a portion of the cladding that surrounds the core of an optical fibre may be removed, for example by etching, to produce a region in which the core of the fibre is less tightly constrained than in adjacent (fully clad) regions. With this arrangement also differential elongation will occur in the core and a strain gradient will be induced in the core of the fibre when a force is applied to one end of the fibre or different forces are applied to the opposite

ends of the modified portion of the fibre.

In yet another form of the invention, a portion of the length of an optical fibre may be tapered so that the core of the fibre will be less tightly constrained by the core cladding at the larger end of the taper than at the narrow end of the taper. Then, here again, a strain gradient will be imposed on the core of the fibre as a consequence of the differential constraining forces that are exerted on the core of the fibre and the resultant differential elongation of the core when the core is subjected to a force which may be resolved to include a tensile component.

Each of the above forms of the invention has application to an in-fibre Bragg grating. Thus, the invention in one of its applications may be defined as providing a method of varying the characteristics of an in-fibre grating and which comprises loading the fibre and, by use of a cladding, constraining a portion of the fibre that contains the grating in a manner such that the grating-containing portion of the fibre is differentially elongated in the direction of light propagation whereby a strain gradient is induced in the grating-containing portion of the fibre in the direction of light propagation.

The present invention also provides an in-fibre grating when produced by the above defined method.

The cladding substance used in constraining the fibre (and when added to the conventional fibre cladding) will be selected in terms of its properties and be deposited to a thickness and configuration to provide the degree of strain gradient required in a given application of the invention. The cladding substance will typically comprise glass, a thermoplastics material, a thermosetting plastics material, a glue or a silicone rubber composition.

The manner of forming the cladding or modifying an existing cladding (for example by tapering or etching a clad optical fibre) will also be determined by the strain

gradient required to be imparted to the grating, the extent to which the spectral width of the grating is to be modified and, hence, the degree of constraint to be imposed on the fibre along the length of contact or at various regions along the length of contact with the cladding.

The load may be applied to the fibre by applying a tensile load to one end only of the fibre, with the other end being anchored either by an external anchor or by the cladding material itself. In an alternative arrangement, the differential expansion and, thus, the strain gradient may be enhanced by applying different tensile loads to opposite ends of the fibre.

The present invention may also be adapted to sensor devices that are arranged to detect for and/or provide a measure of environmental conditions such as temperature or pressure. For this application of the invention a light transmitting device incorporating a grating may be clad in a manner such that a variation in a prevailing environmental condition will cause or tend to cause a change in the dimension or shape of the cladding sufficient to change constraining forces exerted on the light transmitting device by the cladding. Then, with the imposition of a differential constraining force on the device, a strain gradient will be induced in the device which varies with changes in shape or dimension of the cladding and, thus, with changes in the environmental condition.

In a particular embodiment of a sensor device of the type above described, a length of optical fibre containing a Bragg grating may be enveloped in part by a conically shaped or a tear-shaped cladding. Then, if the cladding is exposed to a change in environmental pressure a differential constraining force will be imposed on the clad portion of the fibre, being different at the small and large diameter ends of the cone. Also, the dimensional variation in the cladding will cause a tensile load to be imposed on the fibre which, together

with the differential constraining force, will cause differential elongation of the fibre, resulting in the creation of a strain gradient within the fibre. As indicated above, with the induction of a strain gradient, the reflectivity of the grating will change and a measure will be provided of pressure within the environment in which the device is located.

The invention will be more fully understood from the following description of a procedure that has been employed in the tuning of an in-fibre Bragg grating to produce a chirped grating and of devices that provide for variation of the light transmitting properties of fibres. The description is provided with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Figure 1 shows a schematic illustration of a set-up used in the procedure,

Figure 2 shows a graph of tensile loading applied to an optical fibre in use of the arrangement shown in Figure 1,

Figure 3 shows graphs of reflectance against wavelength characteristics for an in-fibre grating that is subjected to different tensile loadings and supported by variously formed substrates,

Figure 4 shows a set-up similar to that of Figure 1 but with provision for applying different loads to opposite ends of the optical fibre,

Figure 5 shows an in-fibre grating device whose transmitting properties may be varied by imposing and varying a strain gradient in the grating-containing portion of the fibre,

Figure 6 shows in a diagrammatic way an active portion of a sensor device to be used for measuring or detecting changes in fluid pressure,

Figure 7 shows a device which embodies the invention and which may be employed to effect phase shifting of light propagated through the device, and

Figure 8 shows a diagrammatic representation of a device of the type shown in Figure 1 and an apparatus for use in establishing a permanent strain gradient within a grating-containing portion of an optical fibre.

MODES FOR CARRYING OUT THE INVENTION

An in-fibre Bragg grating is first fabricated by holographically side-writing a length of photosensitive optical fibre in an apparatus comprising a compound beam expander and folding prism. The technique employed in this process is well understood and does not form a part of the present invention.

As shown in Figure 1 of the drawings, the length of optical fibre 10 containing the Bragg grating is supported 3 mm above a glass base 11 and glue is applied to form a cladding 12 for the optical fibre 10. As is apparent from the drawings, the cladding 12 is additional to the conventional silica cladding that clads the core of the optical fibre. The cladding/glue 12 is used also to bond the fibre 10 to the base 11. The glue is applied in stages to form the cladding 12 and cover the length of fibre containing the entire grating.

Placing the optical fibre 3 mm above the base 11 represents an optimum arrangement. Gluing the optical fibre too close to the base diminishes the degree of strain gradient along the axial length of the fibre, whilst locating the fibre too high above the base creates a mechanically unstable structure.

Tension is applied to the portion of the optical fibre that contains the grating by attaching weights 13 to a cord 14 which is separately glued at position 15 to the fibre at the end of the cladding 12 that is closest to the weight 13. The tension within the optical fibre is established as a consequence of the fibre being positively connected to the base 11 by way of the cladding 12, but the tensile stress within the optical fibre diminishes with distance along the length of the fibre within the cladding as a consequence of the tensile force being transferred progressively to the base 11 from

the optical fibre by way of the bulk of the cladding 12.

Thus, as indicated in Figure 2, the tensile stress within the fibre increases from a minimum level at the end of the cladding 12 which is remote from the weight 13 to a maximum level at the end of the cladding which is closest to the weight 13. The cladding/glue 12 functions to constrain the optical fibre over the portion of the length of the fibre that is positioned within the cladding. Then, because the tensile stress within the optical fibre diminishes as a function of distance from the weight 13, the optical fibre is caused to elongate differentially over the portion of its length that is constrained by the cladding/glue 12. That is, incremental portions of the length of the optical fibre elongate by an amount different from adjacent incremental portions, so that a greater degree of elongation within the cladding occurs at a position near the weight 13 than at a portion remote from the weight.

The cladding/glue 12 is applied uniformly in a quantity required to produce a desired wavelength shift. A semiconductor photodiode 15 and a spectrum analyser 16 are connected to the optical fibre to permit recording of the wavelength shift and, as will be mentioned below, to permit recording of the spectral profile.

The response of the grating in terms of providing a desired centre frequency shift is varied by changing the amount of glue uniformly applied to the optical fibre, and the required spectral profile or wavelength spread is achieved by modifying the geometrical configuration of the cladding/glue 12. Thus, after the fibre has been tensioned by the weight 13 to provide a maximum desired wavelength shift, a required wavelength spread is then achieved by modifying the configuration of the cladding/glue 12 and, hence, modifying the constraining force exerted on the grating portion of the optical fibre 10 at axially spaced locations along the fibre within the cladding/glue.

By loading the fibre and building the cladding/glue

to meet required conditions, the frequency shift and grating chirp are effectively controlled independently of one another. In the procedure described with reference to Figure 1, a shift of 7 nm has been achieved, the shift occurring at the rate of 12.8 nm per kilogram weight. This may be compared with the requirement to expose the optical fibre to a temperature of 760°C to effect the same shift using the alternative procedure of temperature tuning.

The graphs of Figure 3 show the results of an in-fibre Bragg grating being strained in increments from 0 to 650 gms on one side of the cladding with no tensile loading on the other side, that is with the cladding/glue itself providing the requisite resistance to the loading as a consequence of it being bonded to the base 11. It can be seen that the reflection band width increased from 0.43 nm to 0.94 nm whilst the peak reflectivity reduced from 62% to 35%. The corresponding shift in Bragg wavelength was 0.95 nm.

Figure 4 shows an alternative arrangement to that which is illustrated in Figure 1, with like reference numerals employed to identify like parts. However, the arrangement shown in Figure 4 facilitates a greater degree of control over both the centre frequency shift and spectral profile by providing for a controlled differential in the loading of the two ends of the optical fibre. Thus, the arrangement shown in Figure 4 provides for the addition of a further weight 18 attached to the optical fibre 10 by way of a cord 19 which is in turn secured to the optical fibre at a position 20 adjacent one end of the cladding 12.

In an alternative arrangement, the optical fibre 10 may be loaded at one or both ends of the cladding 12 by one or more tensioning screws connected to the optical fibre either directly or through helical tension springs.

Further variations and modifications may be made in the invention as above described. One such arrangement is shown schematically in Figure 5 in which an optical

fibre 21 contains a Bragg grating 22 which may be post-tuned to vary the Bragg frequency as a function of position along the length of the grating. The fibre 21, which is composed of a clad core, is further clad with a solid cylinder of thermoplastics material 23. The cladding 23 is bonded to the fibre 21 along the full length of the cladding and, thus, relative movement between the fibre 21 and the cladding 23 is constrained.

The cladding cylinder 23 is positioned within and secured to the internal wall of a tubular glass cylinder 24. The cylinder 24 is provided with threaded end portions and mating end caps 25 and 26 are screw-fitted to the end of the glass cylinder.

Mechanical couplers 27 and 28 are positioned at the ends of the cladding cylinder 23 and are connected directly to the optical fibre 21, and helical tension springs 29 are provided to connect each of the couplings 27 and 28 to the respective end caps 25 and 26.

The complete device shown in Figure 5 is equivalent to the arrangement shown in Figure 4 of the drawings and the preceding general description has equal application to Figure 5. Each of the end caps 25 and 26 may be adjusted independently of the other so that different forces may be applied to the fibre at opposite ends of the cladding 23, in the same manner as different weights are applied to the fibre in the arrangement shown in Figure 4 of the drawings.

Figure 6 of the drawings shows a diagrammatic representation of a device which may be employed as an integral part of a pressure sensor which is employed for measuring or detecting variations in the pressure exerted by a confined fluid. In this case the device comprises a length of optical fibre 30 which is coupled to a light source and a spectrum analyser (not shown) in a manner similar to the arrangements shown in Figures 1 and 4. The fibre 30 incorporates an in-fibre Bragg grating 31 and the grating-containing portion of the fibre is located within a tear-shaped cladding 32 of

thermoplastics material. The cladding 32 is bound to the fibre 30 along the full length of the cladding 32 and, as in the case of the previously described embodiments, relative movement between the cladding and the fibre is constrained. When the cladding 32 is subjected to increasing pressure it will tend to elongate in the axial direction of the fibre and, as a consequence, will tend to elongate the fibre itself over its clad length. However, because the fibre is constrained by the cladding the tensile force imposed on the fibre will be dissipated to a greater extent into the more bulky portion of the cladding 32, so that elongation of the fibre under the influence of the tensile force will be greater at the smaller end 33 of the cladding than at the more bulky end 34. Thus, a differential elongation will be imposed on the fibre 30 in the region containing the grating and a strain gradient will be induced in the grating region of the fibre. A measured shift in the Bragg frequency will thus provide a measure of changes in the pressure to which the device is exposed.

Figure 7 shows an embodiment of the invention that may be employed as a phase shifting device. In this case a length of optical fibre 35 containing an in-fibre Bragg grating 36 is embedded in a cladding 37 which is composed of three integrally formed sections 38, 39 and 40, the two outer sections of which have a larger cross-section than the inner portion 39. This provides an arrangement in which, when a tensile load is applied to the fibre from one or both ends of the cladding, a strain gradient will be induced in each of the clad regions 38 to 41 but, because a lower constraining force will be exerted on the fibre 35 in the intermediate region 39, a greater degree of elongation will occur in the optical fibre in the inner region. This will result in a phase shift, that varies with load, between the period of the grating sections in the two enlarged portions 38 and 40 of the cladding.

Figure 8 shows schematically an arrangement in which

an in-fibre grating may be post-tuned in a manner to preserve a required strain gradient in the grating after removal of an external force that is applied to establish the strain gradient.

In the arrangement shown in Figure 8, an optical fibre 43 having an in-fibre grating 44 is supported upon a substrate 45 and clad with a cladding 46 which is adapted to set and be cured by application of UV radiation. The arrangement is set up and loaded in substantially the same manner as that described with reference to Figure 1, but a mask 47 is interposed between the cladding 46 and a UV source 48. The mask is provided with a slit 49 and the mask is moved in the direction indicated by arrow 50 to move the slit incrementally along the length of the cladding 46.

Prior to each incremental exposure of the cladding 46 to the UV radiation, a tensile force F is applied to the fibre 43 for the purpose of imposing stress on and, hence, strain in the incremental portion of the fibre that is aligned with the slit 49. Then, by adjusting the load following each incremental exposure of the cladding, a strain gradient will be created in the fibre with the fibre being constrained by the cladding.

CLAIMS:

1. A method of varying the transmitting properties of a light transmitting device, the method comprising loading and, by use of a cladding, constraining the device in a manner such that the device is differentially elongated over at least a portion of a length of the device in the direction of light propagation whereby a strain gradient is induced in the device in the direction of light propagation.

2. The method as claimed in claim 1 wherein the light transmitting device comprises an optical fibre having a core and a silica cladding.

3. The method as claimed in claim 1 wherein the optical fibre is constrained by a constraining cladding which is applied to at least one localised portion of the length of the optical fibre and bonded to the silica cladding of the fibre.

4. The method as claimed in claim 3 wherein the optical fibre is loaded by application of a tensile force to one end of the optical fibre.

5. The method as claimed in claim 3 wherein the optical fibre is loaded by application of oppositely directed tensile forces to the optical fibre at each side of the constraining cladding, and wherein the oppositely directed tensile forces are different in magnitude one from the other.

6. The method as claimed in any one of claims 1 to 5 wherein the cladding comprises a material selected from glass, thermoplastics material, thermosetting plastics material, glue and silicone rubber.

7. The method as claimed in any one of claims 3 to 6 wherein the optical fibre is embedded within the constraining cladding and the constraining cladding is supported upon a substrate.

8. The method as claimed in any one of claims 3 to 7 wherein the constraining cladding is applied to the optical fibre in an amount and in a configuration which is varied to provide a predetermined degree of strain

gradient within the optical fibre.

9. The method as claimed in claim 2 wherein the silica cladding of the optical fibre is employed to constrain the core of the optical fibre when the optical fibre is subjected to loading, and wherein a portion of the silica cladding that surrounds the core of the optical fibre is removed to produce a region in which the core of the fibre is less tightly constrained than in adjacent regions from which the silica cladding is not removed.

10. The method as claimed in claim 2 wherein a portion of the length of the optical fibre is tapered so that the core of the optical fibre is less tightly constrained by the silica cladding at the larger end of the taper than at the narrower end of the taper whereby, when the load is applied to the optical fibre, a strain gradient is induced in the core of the optical fibre as a consequence of the differential constraining force exerted on the core of the fibre and resultant differential elongation of the core of the fibre.

11. The method as claimed in any one of claims 3 to 10 wherein incremental portions of the constraining cladding are progressively set and wherein, prior to setting of successive incremental portions of the constraining cladding, the loading applied to the optical fibre is changed incrementally so that a strain gradient is progressively established within the optical fibre and the optical fibre is progressively constrained by the cladding in a manner to preserve the strain gradient following removal of the applied loading.

12. The method as claimed in claim 11 wherein the constraining cladding is composed of a material which is set when exposed to UV radiation and wherein incremental portions of the cladding are exposed to the radiation through a mask.

13. A method of varying the characteristics of an in-fibre grating, the method comprising loading a length of optical fibre that contains the grating and, by use of

a cladding, constraining a portion of the fibre that contains the grating in a manner such that the grating-containing portion of the fibre is differentially elongated in the direction of light propagation, whereby a strain gradient is induced in the grating-containing portion of the fibre in the direction of light propagation.

14. The method as claimed in claim 13 wherein the optical fibre is constrained by a constraining cladding which is applied to at least one localised portion of the length of the optical fibre and bonded to a silica cladding that encases a core of the optical fibre.

15. The method as claimed in claim 13 wherein the optical fibre is loaded by application of a tensile force to one end of the optical fibre.

16. The method as claimed in claim 13 wherein the optical fibre is loaded by application of oppositely directed tensile forces to the optical fibre at each side of the constraining cladding, and wherein the oppositely directed tensile forces are different in magnitude one from the other.

17. The method as claimed in any one of claims 13 to 16 wherein the portion of the optical fibre that embodies the grating is embedded within the constraining cladding and the constraining cladding is deposited on a substrate.

18. The method as claimed in any one of claims 13 to 17 wherein the constraining cladding is applied to the optical fibre in an amount and in a configuration which is varied to establish a predetermined reflectance characteristic for the grating, and wherein a light emitting device and a spectrum analyser are connected to the optical fibre to record changes in the spectral profile of the grating during variation of loading applied to the optical fibre and application of the constraining cladding to the optical fibre.

19. A method of varying the transmitting properties or characteristics of a light transmitting device,

substantially as hereinbefore described with reference to the accompanying drawings.

20. A light transmitting device which comprises a light transmitting portion and a cladding portion, the light transmitting portion having a region which is subjected to a strain gradient in the direction in which light is propagated through the device, the strain gradient being created within the device by loading the device and, using the cladding portion of the device, constraining the light transmitting portion in a manner to effect differential elongation of at least a portion of the length of the light transmitting portion in the direction of light propagation.

21. The device as claimed in claim 20 wherein the light transmitting portion comprises an optical fibre having a core and a silica cladding.

22. The device as claimed in claim 21 wherein the optical fibre is constrained by a constraining cladding which is applied to at least one localised portion of the length of the optical fibre and bonded to the silica cladding of the fibre.

23. The device as claimed in claim 21 or claim 22 wherein the optical fibre is embedded within the constraining cladding and the constraining cladding is supported by a substrate.

24. The device as claimed in any one of claims 20 to 23 wherein the optical fibre embodies an in-fibre grating.

25. A light transmitting device comprising an optical fibre having a core portion and a silica cladding portion, a grating formed within the core portion of the optical fibre, and a constraining cladding bonded to the silica cladding of the optical fibre, the portion of the optical fibre core that contains the grating being subjected to a strain gradient in the direction of light propagation through the device, and the strain gradient being created within the optical fibre by loading the optical fibre and, using the constraining cladding,

constraining the optical fibre in a manner to effect differential elongation of at least a portion of the length of the optical fibre in the direction of light propagation.

26. The device as claimed in claim 25 wherein the constraining cladding is applied to at least one localised portion of the length of the optical fibre.

27. The device as claimed in claim 25 wherein the optical fibre is embedded within the constraining cladding and the constraining cladding is supported by a rigid supporting element.

28. The device as claimed in claim 25 wherein the constraining cladding has a cross sectional area which diminishes from one end of the cladding to the other end of the cladding in the direction of light propagation through the device.

29. The device as claimed in claim 25 and in the form of a phase shifting device, the device having a constraining cladding which is composed of three integrally formed portions which are aligned in the direction of light propagation through the device, wherein two outer ones of the cladding portions have a cross-sectional dimension which is larger than that of the intermediate portion of the cladding.

30. A light transmitting device comprising an optical fibre having a core portion and a silica cladding portion, a grating formed within the core portion of the optical fibre, a constraining cladding bonded to the silica cladding of the optical fibre, a casing containing a portion of the length of the optical fibre and having a wall portion to which the constraining cladding is bonded, and means within the casing arranged to apply a tensile loading to the optical fibre in the direction of light propagation through the optical fibre, whereby a strain gradient is created within the optical fibre as a consequence of the constraining cladding constraining the optical fibre in a manner to effect differential elongation of a portion of the length of the optical

fibre in the direction of light propagation through the fibre.

31. A light transmitting device as shown in the accompanying drawings and substantially as hereinbefore described with reference thereto.

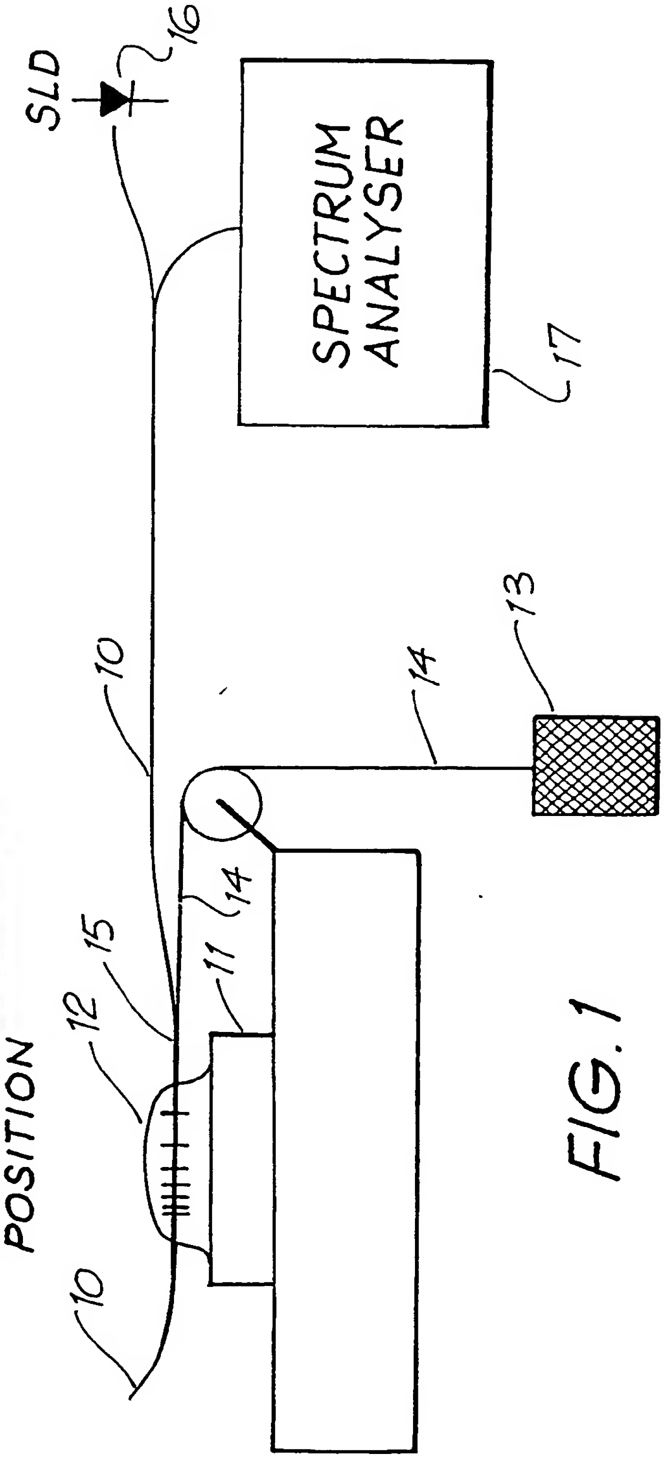
SLD
16
SPECTRUM ANALYSER
17
10
14
13
15
12
11
14
10

FIG. 1

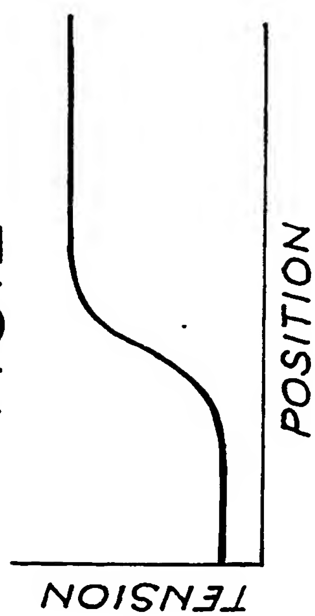
TENSION
POSITION

FIG. 2

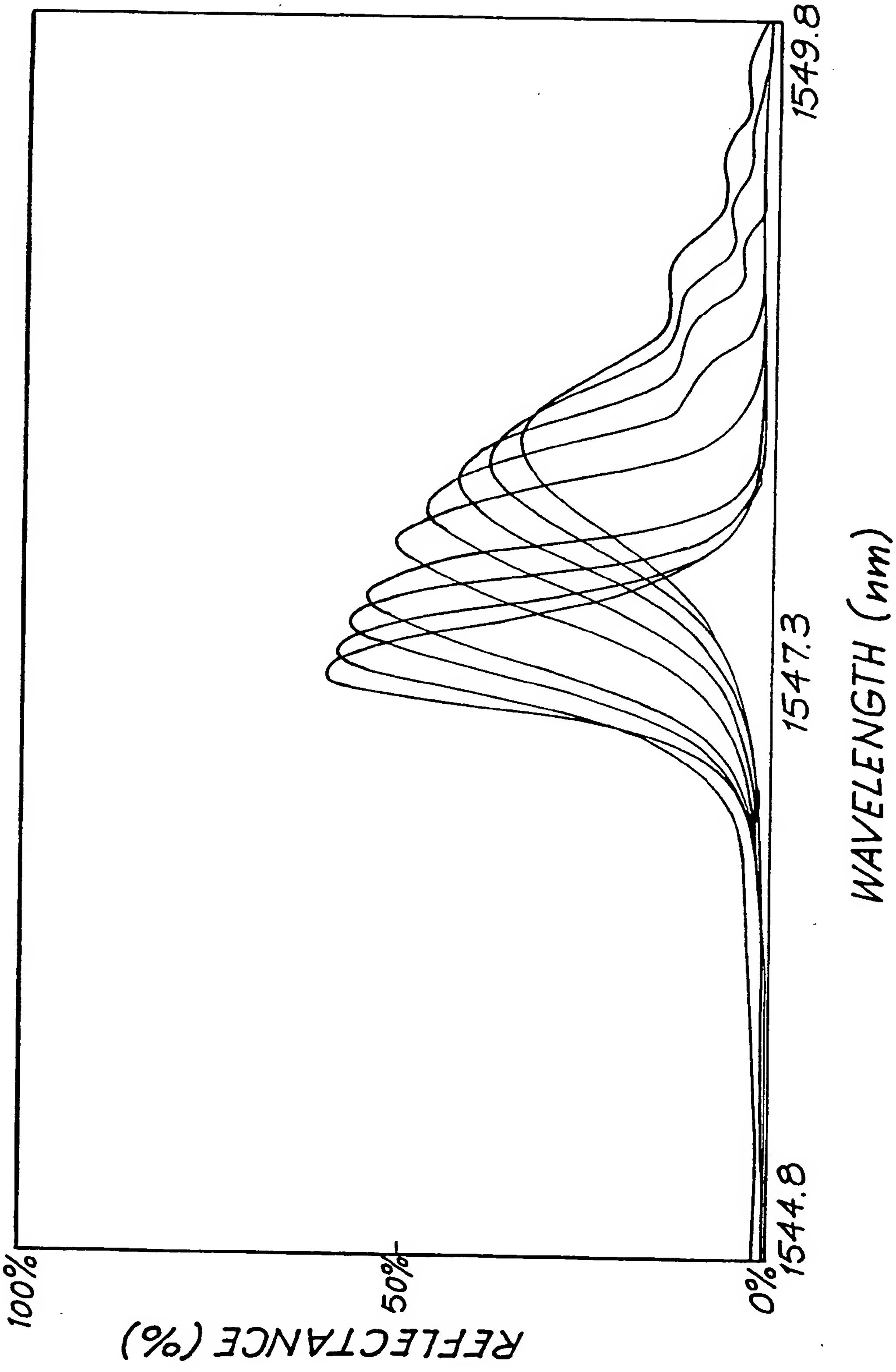

FIG. 3

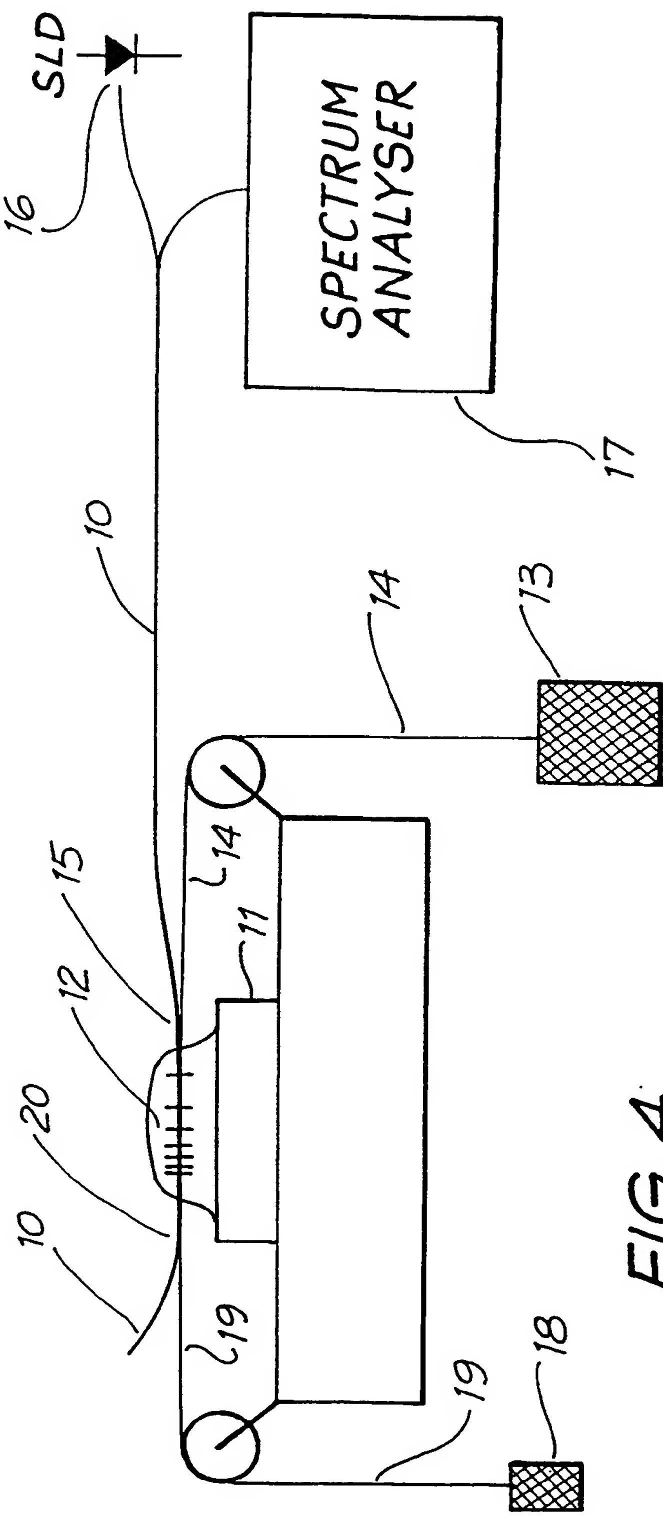

FIG. 4

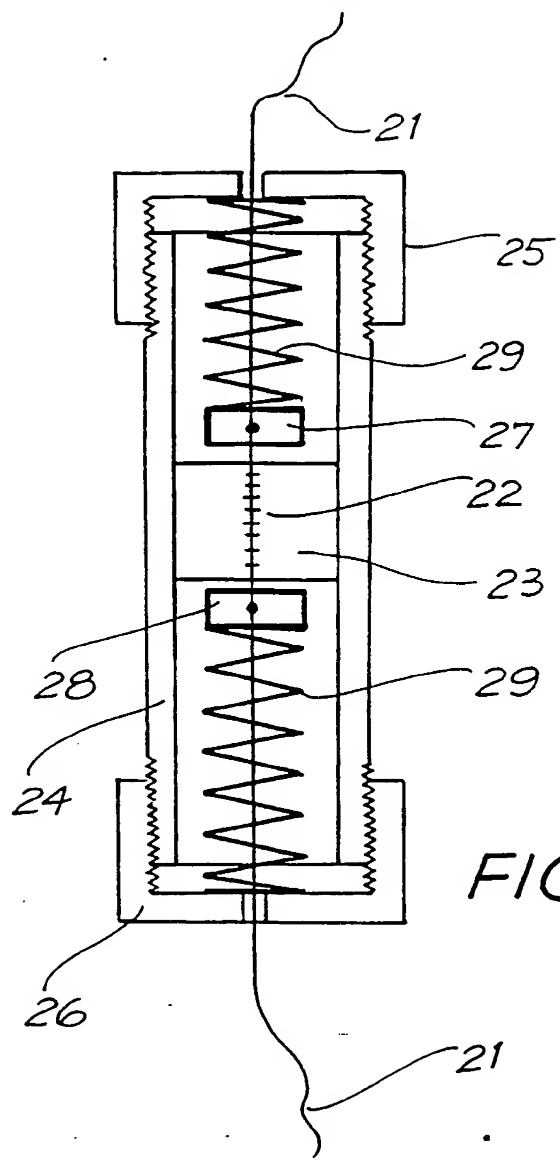

FIG. 5

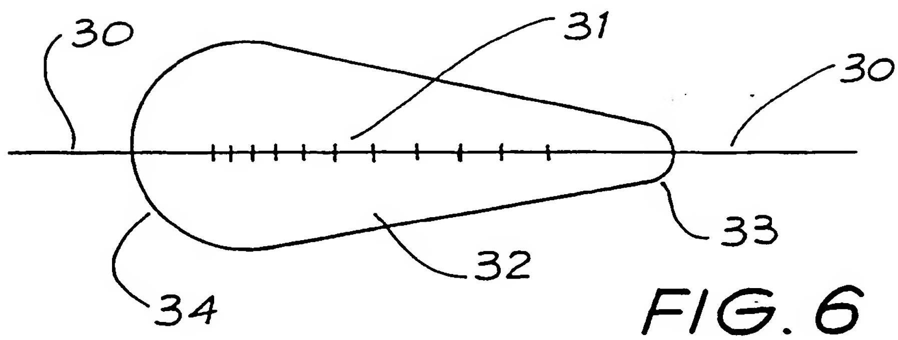

FIG. 6

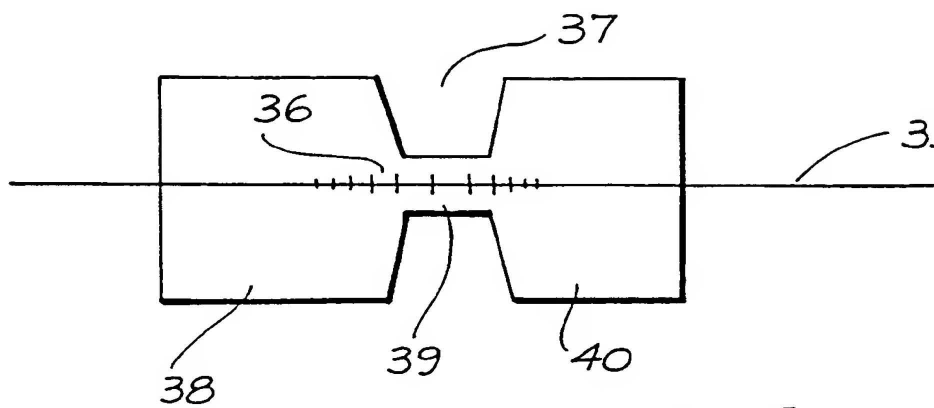

FIG. 7

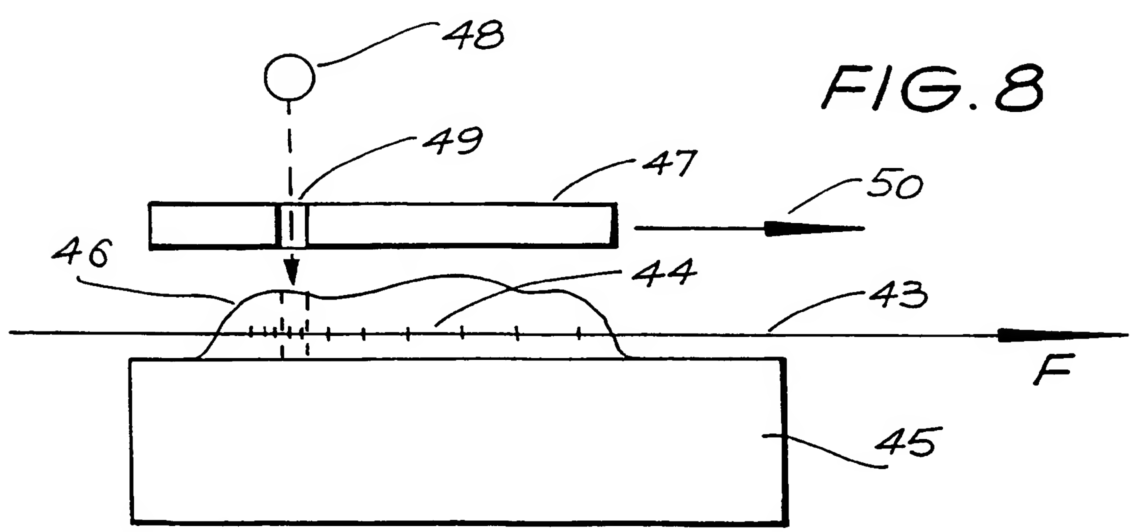

FIG. 8

INTERNATIONAL SEARCH REPORT

International application N .
PCT/AU 95/00263

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.^{6} G02F 2/02, 1/01,1/19, G02B 6/16, 6/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC G02F 2/02, 1/01, 1/19, 1/00, 2/00, G02B 6/16, 6/10, 5/172, 5/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)
DERWENT) (ELONGAT, EXTEND OR STRETCH) and (STRESS, STRAIN, TENS, FORCE OR LOAD)
JAPIO)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	EP 033070 A2 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 5 August 1981 page 8, lines 4-14, Fig.2	1,6,20
X Y	GB 1488253 A (DAVIES et al) 12 October 1977 page 1 lines 85-90, page 2 lines 31-38, Fig.2	1,6,7,20 2,3,21-23
Y	WO 85/01802 A1 (BRITISH TELECOMMUNICATIONS PLC) 25 April 1985 page 5 lines 19-27, page 8 lines 1,5,6,21, Fig 1	2,3,21-23

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 August 1995	16 AUGUST 1995

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	M.E. DIXON Teleph ne N . (06) 2832194

C(Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
A	US 5105300 A (GNEHM) 14 April 1992 col 8 lines 5-25, Fig.9	
A	US 5012679 A (HAEFNER) 7 May 1991	
A	US 4996884 A (LESSING) 5 March 1991	
A	US 4900920 A (FEDERMANN et al) 13 February 1990	
A	US 4050027 A (PFISTER et al) 20 September 1977	
A	GB 1536340 A (STANDARD TELEPHONES AND CABLES LIMITED) 20 December 1978	
A	DE 3415855 A1 (LICENTIA PATENT-VERWALTUNGS GmbH) 7 November 1985	
A	Derwent Abstract Accession No.90.018599/03, Class V07, JO 1298037 A (FUJI, PHOTO FILM KK) 1 December 1989	
A	Patent Abstracts of Japan, p-267, page 149, JP 58-223733 A (FURUKAWA DENKI KOYO K.K.) 26 December 1983	

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
EP	33070	CA	1159916	DE	3166216	JP	56109306
		US	4294507				
WO	8501802	AT	45632	CA	1276824	DE	3479448
		EP	162064	JP	61500458	US	4923278
US	5105300	CA	2056563	GB	2251495		
US	5012679	AT	58435	DE	3701548	EP	342192
		JP	2501947	WO	8805529	DE	3701632
US	4996884	AT	91020	CA	2008137	DE	3901845
		EP	379650	ES	2042931	JP	2228531
US	4900920	DE	3638345	EP	267381		
US	4050027	FR	2360903	GB	1571159		
GB	1536340	AU	25874/77	US	4142774		

END OF ANNEX